THE EFFECTS OF EVALUATIVE AND NON-EVALUATIVE FEEDBACK ON SEQUENTIAL BEHAVIOR IN PSYCHIATRIC ILLNESS

By

JAMES LEE DOWIS

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA
April, 1964

Acknowledgments

The author wishes to thank the members of his supervisory committee: Drs. Wilse B. Webb, Louis D. Cohen, Henry S. Pennypacker, and Charles M. Morris for advice and helpful criticism in the planning and presentation of this study. In particular, he wishes to thank the Chairman of that committee, Dr. Herbert D. Kimmel, for his constant support and effective guidance in all phases of this work. Thanks are due also to Mr. Horace I. Gillett for help in the processing of data and to Mrs. Virginia Dowie for a critical reading of the manuscript. The analytic procedures used in this study were developed while the author was a National Institute of Mental Health (NIMH) predoctoral fellow and the present investigation was supported by NIMH grant number M-2721.

Table of Contents

Page
Acknowledgments ii
List of Tables. iv
List of Figures vi
Introduction. 1
Method. 9
Results 15
Discussion. 35
Summary 50
Appendix A. 54
Appendix B. 68
References. 79
Biographical Sketch 82

List of Tables

Table Page

1. Means and Standard Deviations for Age, Education and Hospitalization of Experimental Groups 10

2. Values of Information Measures 16

3. Values of *F* for Differences Between Amounts of Total Sequential Constraint 19

4. Stereotypic Response Patterns Exhibited by *S*s under All Conditions of Feedback . . . 29

5. Stereotypic Response Patterns Exhibited by Ss under Conditions of Evaluative Feedback. 30

6. Stereotypic Response Patterns Exhibited by Ss under Conditions of Non-Evaluative Feedback. 31

7. Actuarial Description of Normal Subjects. . 56

Non-feedback Frequencies of Response Tetrads for Normal Subjects. 57

Evaluative Feedback Frequencies of Response Tetrads for Normal Subjects 58

Non-evaluative Feedback Frequencies of Response Tetrads for Normal Subjects. . . 59

Actuarial Description of Psychoneurotic Subjects. 60

Non-feedback Frequencies of Response Tetrads for Psychoneurotic Subjects. 61

Evaluative Feedback Frequencies of Response Tetrads for Psychoneurotic Subjects . . . 62

List of Tables--Continued

Table Page

7.--Continued

Non-evaluative Feedback Frequencies of Response Tetrads for Psychoneurotic Subjects. 63

Actuarial Description of Schizophrenic Subjects. 64

Non-feedback Frequencies of Response Tetrads for Schizophrenic Subjects 65

Evaluative Feedback Frequencies of Response Tetrads for Schizophrenic Subjects. . . . 66

Non-evaluative Feedback Frequencies of Response Tetrads for Schizophrenic Subjects. 67

List of Figures

Figure Page

1. Amount of total sequential constraint for feedback conditions and groups: normal (N), psychoneurotic (P), and schizophrenic (S) 18

2. Non-feedback values for amounts of response predictability given by knowledge of previous responses (presponses). . . 23

3. Evaluative feedback values for amounts of response predictability given by knowledge of previous responses (presponses). 24

4. Non-evaluative feedback values for amounts of response predictability given by knowledge of previous responses (presponses). 25

INTRODUCTION

When a person is asked to generate a random series of responses he does not respond randomly (Bakan, 1960). Instead, he exhibits a serial response patterning characterized by *sequential constraint* in which any given response is influenced, to a greater or lesser extent, by previous responses (preresponses). The importance of sequential constraint has been reported for a number of human activities. Goodfellow (1938) has shown that sequential response constraint accounted for many of the "significant" results of the Zenith radio experiment in telepathy. Senders (1953) has demonstrated the presence of sequential constraint in the setting of psychophysical experimentation. Anderson (1960) has discussed the effects of sequential response constraint on asymptotic response levels in the probability learning situation.

In general, these investigations suggest that the amount of sequential constraint between preresponse and response is determined by the characteristics of *feedback* given to the individual about the outcome of his responses.[1] Two primary characteristics of feedback appear to influence the sequential constraint of presponse-response contingencies: (1) the informational characteristics of feedback, and (2) the evaluative characteristics of feedback. This distinction between information and evaluation may be clarified, operationally, by considering two feedback situations.

---

[1] English and English (1958) define "feedback" as ". . . signaling of the degree of performance or nonperformance of an operation." In the present study, the *operation* to be examined is response. The *signaling* to be examined is the *immediate consequence* of responding.

Suppose that when a person gives a response one of two feedback signals is systematically forthcoming: (1) a verbal response of "Right" or (2) the presentation of a triangle. Both of these feedback signals are equally informative in the sense of establishing a definite response-feedback contingency. However, unlike the triangle, the verbal signal of "Right" connotes a sense of evaluative praise. A third possibility also is implicit in the situation described above. Suppose that a response is followed by no systematic feedback signal from the environment. In this case, the person is functioning in what may be operationally defined as the absence of external feedback, a condition which is neither evaluative nor informative.

Studies of normal persons indicate that the absence of external feedback maximizes the sequential constraint of presponse-response contingencies. Senders and Sowards (1952), in reviewing the literature for normals, found almost complete support for this maximizing effect in sequential ordering tendencies associated with psychophysical judgments. For psychiatric patients, Yacorzynski (1941) has suggested a relationship between psychotic illness and the sequential ordering of response. In the absence of external feedback, he found that the preponse-response contingencies of psychotics showed ". . . a different principal of selection" from that employed by normals (Yacorzynski, 1941, pp. 405-406). However, Skinner (1942) criticized both the method of this study and the rather complex interpretation of response contingencies as "principles of selection." Skinner suggested that all of the findings could be explained by a single statement, ". . . the psychotic differs from the normal in being uninfluenced by his own past behavior" (Skinner, 1942, p. 502).

Studies of normal individuals functioning in the presence of informative feedback suggest that, over a long series of trials, the frequency of any given response is proportional to the number of differential feedback events which are associated with that response (Grant, Hake, and Hornseth, 1951; Estes, 1959). However, Anderson (1960) reports the failure of learning models, based on this response paradigm, to predict the asymptotic levels of preponse-response contingency. Hake and Hyman (1953), Bennett, Fitts, and Noble (1954), and Anderson (1960) all report that normal subjects (*Ss*) do not respond entirely on the basis of feedback information. They found that, even in the presence of informative feedback, *Ss* used the sequential response contingencies of their own previous behavior as an effective determinant of future responses.

The effects of informative feedback on sequential constraint in psychopathologic illness are not reported in the literature.

Studies of the evaluative characteristics of feedback have not been designed in such a way as to reveal the sequential nature of response contingency. However, indirect evidence is provided in the literature of instrumental learning. Comparison of normal with psychotic groups indicates that evaluative feedback is not equally facilitative of the learning process in both groups (Garmezy, 1952; Cohen, 1956; Atkinson and Robinson, 1961). While these investigators disagree about the specific effects of positive and negative evaluation, there is general agreement that both forms of evaluative feedback are less facilitative of learning for psychotic than for normal individuals.[2]

An overview of these investigations suggests that the amount of sequential response constraint between responses and response is determined by the informational and evaluative characteristics of feedback. Sequential constraint is maximized by the absence of external feedback and, under these conditions, response constraint is less pronounced for psychotic than for normal individuals. The presence of informative feedback tends to reduce, but not eliminate, sequential constraint in the presponse-response contingencies of normals. Evidence suggests that the presence of evaluative characteristics in feedback signals is associated with differences in the efficiency of instrumental learning for normal and schizophrenic groups. However, it should be emphasized that no direct evidence is available concerning the effects of information or evaluation on sequential response constraint in psychopathologic illness.

---

[2] Controversy in the literature concerns the relative facilitation associated with positive and with negative evaluation. The present study was designed, not to compare the relative effects of these two types of evaluation, but to investigate the effects of evaluative feedback, *per se*, as compared with performance under conditions of non-evaluative feedback.

The present investigation was designed to study response sequences in a two-choice task with amount of sequential constraint in presponse-response contingencies as the primary dependent variable. Groups of normal, psychoneurotic and schizophrenic Ss were asked to generate a series of choices under three conditions of feedback: (1) the absence of external feedback, (2) the presence of evaluative feedback, (3) the presence of non-evaluative feedback.

Data obtained in the absence of external feedback provided a stable estimate of sequential response constraint with which to compare the effects of evaluative and non-evaluative feedback. In addition to their use as a baseline, these data were employed in examining the following predictions.

Hypothesis 1: The Absence of External Feedback

1. All groups of Ss are maximally sensitive to their own previous behavior. Therefore, relative to performance in the presence of both evaluative and non-evaluative feedback, the absence of feedback will elicit the highest levels

of sequential constraint in presponse-response contingencies for all groups.

2. Schizophrenic patients will be relatively insensitive to their own previous behavior and will exhibit levels of sequential constraint which are lower than those displayed by normals and psychoneurotic patients.

3. Insensitivity to previous behavior in the absence of external feedback is a specific concomitant of psychosis and is not a characteristic of psychoneurotic illness. Therefore, the sequential constraint of psychoneurotic patients will exceed that of schizophrenics.

The absence of external feedback is assumed to provide no systematic stimulus in the environment to compete with presponses for the control of responding. However, the introduction of feedback creates a situation in which information, conveyed by external response-feedback contingencies, is pitted against *Ss* own presponse-response contingencies as a potentially effective stimulus for future responses. By randomizing and equating the informational characteristics of evaluative and non-evaluative feedback, the design of the present study separated the specific effects of evaluation from the general effects of information. This separation allowed a test of the following additional predictions.

Hypothesis 2: The Presence of Evaluative Feedback

1. The schizophrenic, in attempting to disregard *evaluation*, isolates himself from the *information* conveyed by response-feedback contingencies. Thus, in essence, he

reproduces non-feedback conditions. Therefore, in comparison with non-patient and psychoneurotic *S*s the schizophrenic patient will be relatively uninfluenced by evaluative feedback. He will tend to maintain the level of sequential response constraint associated with performance in the absence of external feedback.

2. Withdrawal from evaluative feedback is a specific concomitant of psychosis but not common to all psychopathologic illness. Evaluation enhances the effects of information on the performance of both normal and psychoneurotic *S*s. For these groups, comparison with non-feedback performance will show a change in sequential constraint which corresponds with the information conveyed by evaluative feedback.

Hypothesis 3: The Presence of Non-evaluative Feedback

1. All groups of *S*s will exhibit a change in sequential constraint, corresponding to feedback information, as compared with their own performance in the absence of feedback.

2. Unlike evaluative feedback, feedback without evaluative characteristics does not produce high levels of anxiety and consequent withdrawal in schizophrenic patients. Thus, schizophrenic insensitivity to previous behavior (as exhibited in the absence of feedback), combined with random feedback information, will reduce the sequential response constraint of schizophrenics below the level exhibited by normals and psychoneurotic *S*s.

3. Normal and psychoneurotic _S_s modify their behavior to correspond with non-evaluative feedback information. However, feedback without evaluative characteristics is less effective in reducing sensitivity to previous behavior than is feedback with evaluative characteristics for these two groups. Thus, sequential response constraint in the presence of non-evaluative feedback will exceed the sequential constraint which these groups exhibit in the presence of evaluative feedback.

METHOD

Subjects

The *Ss* in this study consisted of three groups, equated for age, sex, and educational attainment.[3] The Normal group consisted of 20 persons who were not, and had not been, hospitalized or treated as outpatients for any psychiatric illness. Both patient groups were selected from the inpatient psychiatric unit of the University of Florida Teaching Hospital. The *Ss* were between 20 and 55 years of age, and non exhibited central nervous system impairment.

Ss in the two patient groups were classified on the basis of admission and discharge diagnosis. The Psychoneurotic group consisted of 20 inpatients for whom initial evaluation *and* discharge diagnosis established the presence of psychoneurotic illness and excluded the presence of psychotic manifestations. The Schizophrenic group consisted of 20 inpatients for whom both of these evaluations established the presence of schizophrenic illness. For all patients, the current hospitalization was their first for psychiatric treatment.

---

[3] A summary of pertinent actuarial characteristics for groups is given in Table 1. Appendix A lists the age, sex, education, hospitalization and specific diagnosis of each *S*.

TABLE 1

Means and Standard Deviations for Age, Education and Hospitalization of Experimental Groups

	Age (Years)	Education (Years)	Hospitalization (Days)
Normal			
Evaluative group (*N* = 10)	34.80 ± 9.98	12.90 ± 1.92	
Non-evaluative group (*N* = 10)	34.30 ± 8.46	12.90 ± 2.39	
Total (*N* = 20)	34.55 ± 9.25	12.90 ± 2.16	
Psychoneurotic			
Evaluative group (*N* = 10)	36.20 ± 9.80	12.90 ± 2.12	38.00 ± 22.32
Non-evaluative group (*N* = 10)	35.80 ± 7.25	13.60 ± 2.11	40.20 ± 15.16
Total (*N* = 20)	36.00 ± 8.62	13.25 ± 2.14	39.10 ± 19.11
Schizophrenic			
Evaluative group (*N* = 10)	35.70 ± 10.44	13.40 ± 2.06	75.70 ± 26.75
Non-evaluative group (*N* = 10)	36.00 ± 10.27	12.90 ± 2.26	54.80 ± 26.79
Total (*N* = 20)	35.85 ± 10.36	13.15 ± 2.18	65.25 ± 28.73

Both patient groups were heterogeneous in terms of the variety of specific diagnoses contained in each (e.g., depressive reactions, simple schizophrenic reactions, etc.). In this respect, the patient groups were representative of the University of Florida Teaching Hospital inpatient hospital population over the past three years (Ruffin, Coggins and Dowis, 1964). For this reason it is likely that the two patient samples roughly approximate similarly identified groups in other inpatient units which treat acute psychopathologic illness. The heterogeneity within the two patient groups also would be expected to weaken "groups" as an independent variable, so that any observed differences between the groups would be all the more significant.

Materials

Materials consisted of a two-button response panel, a discrete-events recorder, and a pack of 67 cards, each of which was imprinted with either a red or a blue circle. The response panel was a box, 6 x 9 x 3 inches, on which were mounted two equal-sized buttons. Panel and buttons were painted flat black. The operation of each button was recorded automatically and separately by a discrete-events recorder.

Procedure

Three experimental conditions were employed: (1) nonfeedback (the initial condition for all $\underline{S}$s), (2) evaluative feedback, (3) non-evaluative feedback. Each $\underline{S}$ was tested individually, the *S* being seated before the response panel and facing the experimenter (*E*). Sixty-seven trials were obtained under each feedback condition.

In the initial non-feedback condition, *E* asked *S* to press either of the two buttons on the response panel. The choice was up to *S*. After this initial selection, *E* again asked *S* to press either of the two buttons. At this point, *E* instructed *S* to continue pressing buttons until stopped by *E*. In this task, and in the additional tasks described below, *S*s were allowed to proceed at their own pace.[4] All questions about which button to press were answered by *E* stating that there was no right or wrong way of going about the task, and that *E* was interested only in what *S* did, not in any right or wrong way of pressing the buttons.

This procedure permitted an evaluation to be made of the effects, on sequential choice behavior, of any pre-established set or habitual response tendencies associated with *S*'s prior experiences or with the nature and instructions of the task. It provided a means for differentiating the effects of sequential response tendencies, associated with specific conditions of external feedback, from the effects of those tendencies which occurred in the absence of any systematic feedback from the external environment.

---

[4] Comparison of the total time required to complete the task failed to yield systematic differences among diagnostic groups for any of the three feedback conditions.

After sixty-seven trials had been administered under non-feedback conditions, each of the three groups was divided in half, with one-half of the *S*s receiving evaluative feedback and the other half receiving non-evaluative feedback.[5]

In the evaluative feedback situation, each time *S* pressed a button *E* said either "Right" or "Wrong". Unknown to *S*, these feedback signals were predetermined by a sequentially random schedule of binary alternatives so that feedback was independent of *S*'s responses.[6] Thus, praise or censure were equally frequent over all responses and equally probable for any given response. No rule, not even one based on four previous response-feedback contingencies, permitted *S* to influence the relative frequency with which the choice of either button was evaluated as "Right" or "Wrong".

The other half of each group of *S*s was tested under conditions of non-evaluative feedback, in which each response by S was followed by the presentation of a card which contained either a blue or a red circle. The source of these cards was hidden from the view of Ss in order to avoid the impression of predetermination. In actuality, the schedule for presenting these figures was predetermined in the same manner as that used for the "Right" and "Wrong" signals in evaluative feedback.

---

[5] *S*s were assigned to these sub-groups, prior to experimentation, on the basis of age, sex, and educational achievement. The actuarial characteristics of sub-groups appear in Table 1.

[6] Feedback schedules were obtained by chance entry into the generating period of a 4-free alternative with equal distribution of binary elements. This generating period was obtained in accordance with the method for constructing models of random sequences given by Popper (1959). A specific expression of this procedure might take the following form: 01100011101010010000010111110011. . . .Davis (1961) has established the relationship of such generating periods to Borel's theory of normal numbers. Thus, mathematical simplicity can be achieved by stating that feedback occurred in a non-normal sequence in which each event was 4-free from neighborhood relationships.

The use of sequentially random feedback accomplished two purposes. First, it ensured that identical amounts of information were conveyed by evaluative and non-evaluative feedback.[7] Second, it ensured that, under conditions of evaluative feedback, positive evaluation (i.e., "Right") and negative evaluation (i.e., "Wrong") were equally frequent for each S. By controlling and equating the informational characteristics of evaluative and non-evaluative feedback through randomization, it was possible to obtain data about the effects of evaluation which were not biased by the effects of differences in information. By equating the frequency of positive and negative evaluation it was possible to ascertain the effects of evaluation, per se, in a manner which ensured that differences associated with the specific effects of praise and of censure were equated for diagnostic groups.

---

[7] The term "amount of information" is used here to distinguish the measurement of information from the content or meaning of information. This distinction is amplified in Appendix B.

RESULTS

Data were analyzed by means of multivariate information analysis (McGill, 1954).[8] The results of this analysis appear in Table 2 which lists the *bit* values of information measures averaged across *S*s within groups. A split-half comparison of results revealed no consistent differences between the first and second sets of 32 responses obtained from *S*s.[9] Therefore, Table 2 presents the values of information measures based on total sequences of 64 responses.

Total Sequential Constraint

Bit values of *total sequential constraint* [$T'(1;2;3;4)$] are directly proportional to the orderliness of response-response contingencies in a series of trials; highly ordered series produce high constraint values, randomlike series produce low values. Thus, total sequential constraint values are *positively* related with the extent to which *S*s' responses were influenced by their own previous behavior. In the

---

[8] The derivation of information measures is presented in Appendix B of this report. Frequency data used in computing the values of these measures appear, for each *S*, in Appendix A. These frequency data also were employed in computing the patterns of response given in Tables 4, 5 and 6.

[9] This result concurs with that of Hake and Hyman (1953) who reported consistent values of response-response constraint, for normals, in blocks of 24 responses over a sequence of 230 binary choice events.

TABLE 2

Values of Information Measures

	Normal	Psychoneurotic	Schizophrenic
Non-feedback			
$T'(1;2)$	.28715	.38885	.18051
$T'(1;2,3)$	.44432	.42392	.28154
$T'(1;2,3,4)$	.52390	.48378	.37667
$T'_2(1;3)$	.15716	.03507	.10103
$T'_{23}(1;4)$	.07957	.05986	.09513
$T'(1;2;3;4)$	1.25537	1.29655	.83871
Evaluative Feedback			
$T'(1;2)$	.14577	.05397	.17148
$T'(1;2,3)$	.18050	.13827	.27212
$T'(1;2,3,4)$	.20714	.21316	.36442
$T'_2(1;3)$	.03473	.08431	.10064
$T'_{23}(1;4)$	.02664	.07488	.09238
$T'(1;2;3;4)$	.53341	.40540	.80802
Non-evaluative Feedback			
$T'(1;2)$	.19381	.18566	.09874
$T'(1;2,3)$	.21765	.23828	.10974
$T'(1;2,3,4)$	.23410	.28410	.15506
$T'_2(1;3)$	.02334	.05262	.01099
$T'_{23}(1;4)$	.01644	.04583	.04532
$T'(1;2;3;4)$	.64557	.70804	.36354

evaluative and non-evaluative feedback situations, feedback was presented in a sequentially random fashion. Thus, under conditions of random feedback, the numerical values of total sequential constraint are *negatively* related to the extent to which *Ss* adapted their behavior to accord with the information conveyed by external feedback.

Figure 1 presents the mean amount of total sequential constraint for each of the experimental groups: normal non-patients (N), psychoneurotic patients (P), and schizophrenic patients (S). Table 3 gives the values and probabilities of *F* ratios associated with comparisons of these measures.

In the absence of external feedback, the schizophrenic group exhibited a significantly smaller amount of response constraint than either the psychoneurotic or normal groups (Psychoneurotic vs. Schizophrenic, 1.30 vs. .84, $p < .01$; Normal vs. Schizophrenic, 1.25 vs. .84, $p < .01$). The normal and psychoneurotic groups demonstrated approximately equal values of total sequential constraint. These results indicate that, in the absence of external feedback, schizophrenic patients were less sensitive to their own previous behavior than were psychoneurotic or normal *Ss*.

In the presence of evaluative feedback, schizophrenic patients exhibited a significantly greater amount of response constraint than did *Ss* in either the psychoneurotic or normal groups (Schizophrenic vs. Psychoneurotic, .81 vs. .40, $p < .01$; Schizophrenic vs. Normal, .81 vs. .53, $p < .05$). These results

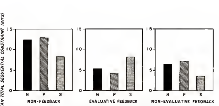

Figure 1.--Amount of total sequential constraint for feedback conditions and groups: normal (N), psychoneurotic (P), and schizophrenic (S).

TABLE 3

Values of *F* for Differences Between Amounts of Total Sequential Constraint

	Normal			Psychoneurotic			Schizophrenic		
	Non-Feedback (*df* = 220)	Evaluative Feedback (*df* = 110)	Non-eval. Feedback (*df* = 110)	Non-feedback (*df* = 220)	Evaluative Feedback (*df* = 110)	Non-evaluative Feedback (*df* = 110)	Non-feedback (*df* = 220)	Evaluative Feedback (*df* = 110)	Non-evaluative Feedback (*df* = 110)
Normal									
Non-feedback									
Evaluative	2.35[b]								
Non-evaluative	1.94[b]	1.21							
Psychoneurotic									
Non-feedback	1.03								
Evaluative		1.32		3.20[b]					
Non-evaluative			1.10	1.83[b]	1.75[b]				
Schizophrenic									
Non-feedback	1.50[b]			1.55[b]					
Evaluative		1.52[a]			1.99[b]		1.04		
Non-evaluative			1.77[b]			1.95[b]	2.31[b]	2.22[b]	

[a] *p* < .05

[b] *p* < .01

contrast with those obtained under non-feedback conditions in which schizophrenic patients showed the smallest value of total sequential constraint. Examination of this reversal shows it was due primarily to a statistically significant decrease in constraint for the normal and psychoneurotic groups while schizophrenic *S*s remained approximately equal in constraint values between non-feedback and evaluative feedback conditions (Normal, non-feedback vs. evaluative, 1.25 vs. .53, *p* < .01; Psychoneurotic, non-feedback vs. evaluative, 1.30 vs. .40, *p* < .01); Schizophrenic, non-feedback vs. evaluative, .84 vs. .81, *p* > .25). These results indicate that evaluative feedback significantly reduced the orderliness of presponse-response contingencies for normals and psychoneurotic *S*s but failed to influence the sequential response behavior of the schizophrenics.

In the presence of non-evaluative feedback, schizophrenic patients exhibited significantly lower values of response constraint than *S*s in the other two groups (Psychoneurotic vs. Schizophrenic, .71 vs. .36, *p* < .01; Normal vs. Schizophrenic, .64 vs. .36, *p* < .01). All three groups showed a significant reduction in sequential response constraint in the presence of non-evaluative feedback as compared with the absence of feedback (Normal, non-feedback vs. non-evaluative, 1.25 vs. .65, *p* < .01; Psychoneurotic, non-feedback vs. non-evaluative, 1.30 vs. .71, *p* < .01; Schizophrenic, non-feedback vs. non-evaluative, .84 vs. .36, *p* < .01). These results indicate that sensitivity to previous behavior was reduced, for *Ss* in all groups, by the presence of non-evaluative feedback. These effects appeared to have been especially pronounced in the behavior of schizophrenic patients.

Comparison of total sequential constraint for normal *Ss*, under the three conditions of feedback, indicates that both evaluative and non-evaluative feedback were effective in reducing sequential response constraint from the baseline values obtained in the absence of feedback. Both types of feedback were about equally effective in producing this result. Evaluative feedback produced a 58 per cent reduction in sequential constraint while non-evaluative feedback accounted for a reduction of 49 per cent.

Psychoneurotic patients also were significantly influenced by both evaluative and non-evaluative feedback. However, in the case of psychoneurotic patients, these two types of feedback were not equally effective in reducing sequential response constraint. Evaluative feedback reduced constraint values by 69 per cent from those values obtained in the absence of external feedback. However, non-evaluative feedback was associated with a reduction of only 45 per cent. This difference was statistically significant (Non-evaluative vs. evaluative, .71 vs. .40, $p < .01$).

In the schizophrenic group the presence of evaluative feedback failed to reduce sequential constraint below the level observed in the absence of feedback. For the schizophrenic group, evaluative feedback reduced constraint by only 4 per cent, a figure which contrasts dramatically with the 57 per cent reduction associated with the presence of non-evaluative feedback. This difference in the behavior of schizophrenics, between evaluative and non-evaluative feedback, was statistically significant (Evaluative vs. non-evaluative, .81 vs. .36, $p < .01$).

Components of Response Predictability

Figures 2, 3 and 4 present the mean values of response predictability associated with the five components of response information reported in Table 2; first presponse alone $[T'(i;2)]$, second presponse alone $[T'_2(i;3)]$, third presponse alone $[T'_{23}(i;4)]$, the joint occurrence of first and second presponses $[T'(i;23)]$, the joint occurrence of first, second and third presponses $[T'(i;234)]$. Response predictability, like sequential constraint, is positively related to the sequential ordering of presponse-response contingencies. As these contingencies approach randomness, but values of response predictability approach zero. Thus, in the presence of random feedback, values of response predictability are negatively related to the information conveyed by random external feedback.

Figure 2 presents the mean values of the components of response predictability exhibited in the absence of external

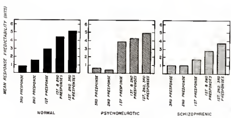

Figure 2.--Non-feedback values for amounts of response predictability given by knowledge of previous responses (presponses).

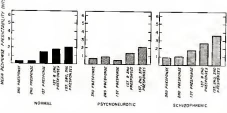

Figure 3.--Evaluative feedback values for amounts of response predictability given by knowledge of previous responses (presponses).

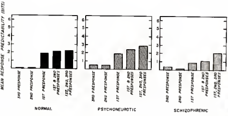

Figure 4.--Non-evaluative feedback values for amounts of response predictability given by knowledge of previous responses (presponses).

feedback. These values indicate that the responses of normal and psychoneurotic Ss were highly predictable in terms of the joint occurrence of two presponses $[T'(1;23)]$ and of three presponses $[T'(1;234)]$. However, these two groups differed markedly in the relative predictability given by first presponse alone $[T'(1;2)]$, second presponse alone $[T'_2(1;3)]$, and third presponses alone $[T'_{23}(1;4)]$. Normal performance was characterized by a stepwise reduction in the value of response predictability for increasingly remote responses. This stepwise reduction indicates that normals were influenced by previous behavior in direct proportion to the recency of that behavior. On the other hand, psychoneurotic performance was characterized by a sharp decrease in response predictability beyond the first presponse level. This sharp reduction indicates that, for psychoneurotics, only the most immediate past behavior was influential in determining the nature of a response. A sharp reduction also characterized the univariate components of response predictability for the schizophrenic group. However, the proportion of this reduction was not as great as that exhibited in psychoneurotic performance. For psychoneurotics, first presponse alone accounted for 81 per cent of response predictability. For schizophrenics, this value was 47 per cent.

Figure 3 presents the mean values of the components of response predictability exhibited in the presence of evaluative feedback. These values show a greater response predictability, based on the joint occurrence of two and of three preresponses, for schizophrenic than for normal or psychoneurotic groups. Normal and schizophrenic performance was characterized by a reduction in response predictability beyond the first preresponse with more distant preresponses contributing equal amounts of predictability. This reduction was sufficiently great that, for both groups, the first preresponse alone accounted for almost one-half of all response predictability. Psychoneurotic performance differed from that of other groups in the relatively low value of response predictability associated with the first preresponse alone. This group exhibited components of response predictability in which all single preresponses were equally predictive of response.

Figure 4 presents the mean values of the components of response predictability exhibited in the presence of non-evaluative feedback. These values show that multivariate components of response predictability [$T'(1;23)$, $T'(1;234)$] were higher for normal and psychoneurotic than for schizophrenic *S*s. In each group more than half of all response predictability was derived from the first preresponse alone [$T(1;2)$]. This component gave 83 per cent of response predictability in the normal group, 65 per cent in the psychoneurotic group, and 64 per cent in the schizophrenic group. Thus, while all groups exhibited a primary dependence on immediate preresponse as a determinant of responding, this effect was especially pronounced for the normal group.

An overview of these results points up a uniformity in the components of response predictability for schizophrenics across all feedback conditions. In each condition, first presponse alone [$T'(1;2)$] accounted for approximately 50 to 60 per cent of all response predictability. This uniformity was in marked contrast to the variable characteristics of components of response predictability for the normal and psychoneurotic groups.

Patterns of Sequential Response

In sequences of four responses, it is possible to distinguish three types of sequential response patterning: (1) repetition, in which each successive response repeats its predecessor (R,R,R,R; L,L,L,L); (2) alternation, in which each successive response alternates from its predecessor (R,L,R,L; L,R,L,R); (3) double alternation, in which repetition and alternation regularly follow each other (R,R,L,L; L,L,R,R; R,L,L,R; L,R,R,L).

Tables 4, 5 and 6 give the number of *S*s who displayed a stereotypic use of any of these response patterns (i.e., on more than one-half of all responses).[10] Table 4 is based on data for all 60 *S*s, and combines the data for evaluative and non-evaluative feedback. Table 5 is based on the data of the 30 *S*s who performed under conditions of evaluative feedback. Table 6 presents data for the 30 *S*s who performed in the non-evaluative feedback condition.

---

[10] These data were obtained by summing the frequencies of the appropriate response tetrads listed in Appendix A.

TABLE 4

Stereotypic Response Patterns Exhibited by *Ss* under All Conditions of Feedback

	Non-feedback				Feedback			
	Repetition	Alternation	Double Alternation	Total	Repetition	Alternation	Double Alternation	Total
Normal (*N* = 20)	5	4	4	13	6	1	0	7
Psychoneurotic (*N* = 20)	2	7	0	9	3	1	2	6
Schizophrenic (N = 20)	2	3	3	8	0	2	1	3
Total (*N* = 60)	9	14	7	30	9	4	3	16

TABLE 5

Stereotypic Response Patterns Exhibited by Ss under Conditions of Evaluative Feedback

	Non-feedback				Evaluative Feedback			
	Repetition	Alternation	Double Alternation	Total	Repetition	Alternation	Double Alternation	Total
Normal (*N* = 10)	3	2	2	7	3	0	0	3
Psychoneurotic (*N* = 10)	1	4	0	5	2	0	2	4
Schizophrenic (*N* = 10)	0	2	2	4	0	1	1	2
Total (*N* = 30)	4	8	4	16	5	1	3	9

TABLE 6

Stereotypic Response Patterns Exhibited by Ss under Conditions of Non-Evaluative Feedback

	Non-feedback				Non-evaluative Feedback			
	Repetition	Alternation	Double Alternation	Total	Repetition	Alternation	Double Alternation	Total
Normal (N = 10)	2	2	2	6	3	1	0	4
Psychoneurotic (N = 10)	1	3	0	4	1	1	0	2
Schizophrenic (N = 10)	2	1	1	4	0	1	0	1
Total (N = 30)	5	6	3	14	4	3	0	7

Table 4 shows that, in the absence of external feedback, 30 *Ss* exhibited stereotypic response patterning. This group of 30 *Ss* was composed of 13 normals, 9 psychoneurotics and 8 schizophrenics. For the normals, each type of response patterning occurred with almost equal frequency (repetition, 5; alternation, 4; double-alternation, 4). This equal distribution also characterized the schizophrenics (repetition, 2; alternation, 3; double-alternation, 3). Psychoneurotic *Ss* exhibited a disproportionately large number of alternation patterns (repetition, 2; alternation, 7; double-alternation, 0). This extensive use of alternation is consistent with the earlier observation that the psychoneurotic group as a whole exhibited extremely high values of response predictability for the first preresponse.

In alternation, knowledge of the immediate predecessor of a given response provides for complete prediction of that response, while knowledge of more remote preresponses does not increase response predictability. Thus, extensive use of alternation produces high values for the first preresponse component of response predictability, and low values for more remote preresponses. In a similar manner, each of the stereotypic response patterns (i.e., repetition, alternation, and double-alternation) are related to values of response predictability as measured by information analysis. The extent of this relationship depends upon the degree to which the frequency of a particular response pattern is disproportionate to the frequency of all other response patterns.[11] Thus, for the psychoneurotic group the presence of 7 *Ss* who use alternation produced a marked elevation in the predictive value of first responses. However, the magnitude of this elevation was produced, *jointly*, by the absence of double-alternation patterns and the extensive use of alternation.

Table 4 shows that the change from non-feedback conditions to conditions of external feedback was accomplished by a marked reduction in the total number of *Ss* who exhibited stereotypic response patterns (non-feedback, 30; feedback, 16). This change was found to be statistically significant ($\underline{X}^2 = 4.97$, $\underline{p} < .05$).

Inspection of Tables 5 and 6 reveals that the reduction of stereotypic response patterns did not differ under conditions of evaluative as opposed to non-evaluative feedback (non-feedback vs. evaluative feedback, 16 dropped to 9; non-feedback vs. non-evaluative feedback, 14 dropped to 7).

An overview of this approach to the data suggests that the use of stereotypic response patterns occurred with almost equal frequency in the sequential choice behavior of normals, psychoneurotics, and schizophrenics. For *Ss* in each of these groups, the absence of environmental feedback was associated with relatively high levels of stereotypic responding. Psychoneurotics displayed a disproportionately large number of alternations, while the behavior of normals and schizophrenics was characterized by approximately equal use of all three response patterns. Comparison of Tables 5 and 6 shows a close correspondence in the total number of *S*s, within each diagnostic group, who displayed stereotypic response patterns. This correspondence was not attributable to bias in the method of selecting *S*s.

---

[11] The nature of this relationship is explained in Appendix B. In general, the indirectness of this relationship is produced by the non-linear function which relates response predictability to the number of responses determined by response patterning.

The introduction of feedback from the external environment was accompanied by a significant reduction in stereotypic patterns of response for all groups of *S*s. This reduction was not restricted to either evaluative or non-evaluative feedback. Both types of feedback were associated with approximately equal reductions in the number of *S*s who made extensive use of sequential response patterns.

DISCUSSION

Two characteristics of the relationship between information and human behavior were examined in this study: (1) the use of information in modifying behavior, and (2) the efficiency of information processing.

Modification of Choice Behavior

Values of total sequential constraint provided a criterion for assessing the effects of feedback conditions on the extent to which behavior was modified to conform with information. Because the informational input characteristics of external feedback were controlled and randomized in this study, values of total sequential constraint have two consistent characteristics: (1) they are positively related to the extent to which responses were associated with information conveyed by previous behavior, and (2) they are negatively related to the extent to which responses were influenced by the information conveyed by external feedback. Thus, in the absence of external feedback, high values of sequential constraint indicate that behavior conformed with information conveyed by previous responses (the only systematic informational input available to the S). In the presence of external feedback, low values of total sequential constraint indicate that behavior was modified to conform with information conveyed by sequentially random, external feedback.[12]

Efficiency of Information Processing

Analysis of the components of response predictability provided criteria for assessing the effects of feedback conditions on the efficiency of information processing. In the present study, these criteria were applicable in evaluating the efficiency of information processing for two input sources: (1) information conveyed by previous behavior, and (2) information conveyed by the joint occurrence of previous behavior and external feedback. Analysis of the joint occurrence of two information sources provided a means for assessing the efficiency with which multivariate inputs were combined under conditions of evaluative and non-evaluative feedback.

Absence of Environmental Feedback

Normal Group

Normal non-patients, in the absence of systematic information from the external environment, tended to use their own previous behavior as an effective determinant of responses. This was evidenced in both the amount of self-regulation (as measured by total sequential constraint) and the number of regulatory prepsonse-response contingencies (as measured by the components of response predictability). The relative values of specific prepsonse-response contingencies were characterized by a stepwise reduction in the value of response predictability for increasingly remote presponses. Thus, self-regulation from previous behavior was directly related to the recency of that behavior.

---

[12] That sequentially random, external feedback can provide information, and that human and sub-human organisms can modify their behavior to accord with this information, has been demonstrated in numerous studies generated by the statistical association theory of learning (Hake and Hyman, 1953 ; Anderson, 1960).

The efficiency of this manner of processing information, stems from the nature of sequentially dependent series. To say that events are "sequentially dependent" is, simply, another way of saying that each event conveys some information about its predecessors. Thus, by responding primarily in terms of the most recent presponse, normals used whatever information this presponse conveyed about its predecessors, while in no way increasing the complexity of informational input. However, it is important to note that the responses of normals were not determined solely by their immediate predecessors.

This fact assumes importance in view of the consistent finding that maximum information transmission for humans is obtained when 5 to 9 alternatives are employed in a univariate input source (Attneave, 1959). In simple binary series (like those generated under non-feedback conditions) the number of alternatives associated with a given sequence of length n is 2^n. Thus, by associating responses primarily with first presponses, yet incorporating second presponses as well, the behavior of normals proved sensitive to between 5 and 8 presponse-response contingencies, a range which closely approximates the established condition for maximally efficient processing of information.

Psychoneurotic Group

Psychoneurotic performance, in the absence of external feedback, resembled that of normals in terms of total sequential constraint among presponses and responses. Thus, normals and psychoneurotics evidenced a common tendency toward using their own previous behavior as a determinant of responses when the external environment provided no systematic feedback. However, analysis of the components of response predictability showed marked differences between these groups in the relative effects of response association with specific presponses. It was apparent in these differences that the psychoneurotic's manner of self-regulation by previous behavior was less efficient in terms of the informational demands of the experimental situation.

The relative inefficiency of information processing by psychoneurotics was shown in the fact that their presponses were almost totally dependent upon their immediate predecessors. More remote presponses were relatively insignificant in determining the nature of responses. This effect was so pronounced that 81 per cent of response association was attributable to the first presponse alone. Thus, when external feedback was absent, the sensitivity of psychoneurotics to their own previous behavior was restricted to the most immediate past event.

Subsequent discussion will show the efficiency of restricting presponse-response associations when dealing with complex input variables. However, sequential choice in the absence of feedback involves a simple univariate series of binary input events. By the exclusive use of a single presponse in determining responses, psychoneurotics reduced the number of influential presponse-response contingencies below that range (5 to 9) associated with maximum information usage. Thus, unlike normals, psychoneurotics imposed what may be termed inefficient restrictions on the use of information conveyed by their previous behavior in the absence of external feedback.

Eriksen and Wechsler (1955) have associated inefficient restrictions on information input with anxiety. These investigators measured the response constraint and information transmission associated with the absolute judgment of visual size under conditions of low and high anxiety. They found that anxiety increased response constraint but neither increased nor decreased total transmission of information. These differences between low and high anxiety groups parallel the differences, in the present study, between the normal and psychoneurotic groups. In view of the well-established anxiety concomitants of psychoneurotic illness, the correspondence of results of these two investigations suggests that the inefficient restricting of information processing exhibited by the psychoneurotic patients in this study may be attributable to the effects of anxiety.

Schizophrenic Group

Schizophrenic performance, in the absence of external feedback, was characterized by the relative independence of present responding from constraint by earlier behavior. When information was not available in the external environment, normals and psychoneurotics substituted information from their own previous behavior as a basis for responding. To a significant extent, the schizophrenics were less sensitive to their own behavior than were the other two groups of Ss and, in the absence of external feedback, exhibited behavior with more chaotic, informational properties.

This reduced use of the self-regulating properties of previous behavior suggests that the schizophrenic may be as cut off from his own self as he is from the outside world. This formulation appears to be at odds with the widespread belief that schizophrenic behavior is "autistic". However, English and English (1958), in defining "autistic" as a state of being ". . . directed unduly toward oneself," stress inappropriateness as a determining characteristic of autism. Additional results from the present study suggest that inappropriate self-regulation, as exhibited by schizophrenics, was related to specific feedback conditions. Therefore, further discussion of autism will be postponed until the results for environmental feedback conditions have been examined.

Environmental Feedback

The introduction of random, external feedback created a situation in which information, conveyed by response-feedback contingencies, was pitted against information, conveyed by presponse-response contingencies, as potential determinants of behavior. To understand the changes in sequential choice behavior that were associated with the effects of evaluation, it is necessary to examine, first, the changes in variable input states which were common to both evaluative and non-evaluative feedback.

The presence of external feedback in the experimental situation influenced the variable input in two distinct ways. First, by adding a second set of binary input events, external feedback geometrically increased the number of variable states associated with a given sequence length. Second, by interposing a set of binary feedback events between response events, the presence of external feedback doubled the length of informative event sequences. In other words, the addition of external feedback to the experimental situation changed the characteristics of total informational input from a univariate, binary sequence to a multivariate, bi-binary sequence.[13]

Pollack (1953) has investigated the efficiency of information processing for sequentially encoded information conveyed by *multivariate* input. In relation to the present study, his work indicates that the efficiency of information processing is determined, exclusively, by the amount of information lost in *combining* input sources. Maximum information loss (hence, minimum efficiency) is assured by information processing which fails to unite multiple input sources, that is, information processing which is based separately on either of two input sources, but does not combine the two (i.e., respond to their joint information). Minimum information loss (thus, maximum efficiency) is assured by information processing which combines the multivariate input in such a manner as to reduce *the length* of the input sequence required to convey a given amount of information (message length). The present results showed that under conditions of both evaluative and non-evaluative feedback, information processing for the normal group was characterized by maximum efficiency (i.e., minimum information loss).

---

[13] Edwards (1954) has shown that, where n is the number of events in a sequence, binary series yield $2n$ variable states and that the alternating juxtaposition of two binary series produces a bi-binary sequence characterized by $2n^2$ variable states. Dowie and Pawliger (1964) have elaborated the restrictions imposed on multivariate information analysis by the necessary entailments of sequential bi-binary data.

Normal Group

It will be remembered that, in processing the univariate input of the non-feedback situation, normals maximized the efficiency of information processing by using information conveyed by more remote presponses. However, in processing the multivariate input associated with the presence of external feedback, normals tended to restrict effective presponse-response contingencies to the most immediate presponse. This reduced the length of input sequence associated with the high values of response predictability. Thus, for normals, the restriction of sequential response constraints served as an efficiency technique for combining the self-regulatory effects of previous behavior with regulatory demands from the external environment.

Psychoneurotic Group

Normals reacted to evaluative and non-evaluative feedback with equal efficiency and adaptability. The reactions of psychoneurotic patients, however, were markedly different under these two conditions of external feedback. In the presence of non-evaluative feedback, the efficiency of information processing and the adaptive use of information were almost identical for the normal and psychoneurotic groups. However, in the presence of evaluative feedback, psychoneurotic patients did not exhibit the efficient integration of self-regulated and externally regulated behavior which characterized the normals.

The inefficient characteristics of information processing by psychoneurotic patients were clearly discernible in the change from the non-feedback condition to the conditions of evaluative feedback. In dealing with *simple* informational demands in the absence of feedback, the psychoneurotic tended to restrict preresponse-response associations to the most immediate preresponse event. This *simplifying* restriction was inefficient, *in that simple univariate situation*, because it reduced the number of variables below the number associated with maximum information gain. On the other hand, in dealing with *complex* informational demands in the presence of evaluative feedback, psychoneurotics extended preresponse-response associations to the point that each of three preresponses were equally associated with responding. This *complicating* extension was inefficient, *in that complex multivariate situation*, because it increased message length beyond that length associated with minimum information loss rather than reducing it to conform with the increased complexity.

A second characteristic of the psychoneurotic's reaction to external feedback was discernible in comparing the use of information conveyed by evaluative feedback with the use of information conveyed by non-evaluative feedback. For psychoneurotics, unlike normals, the extent to which behavior conformed to information from the external environment was significantly lower in the presence of evaluative feedback than in the presence of non-evaluative feedback.

To some extent, differences between normals and psychoneurotics, under the conditions of the present study, are compatible with the general formulations of Spiegel (1959). In comparing psychoneurotic communications with that of normals, she noted a similarity in the overall accuracy with which both groups use information from the external environment. However, she interpreted this similarity as superficial, the end product of different ways of processing information.

Results from the present study give limited support to this interpretation. In two of three feedback conditions, the information processing of psychoneurotics was less efficient than that of the normals. In neither of these conditions was there a difference in the overall extent to which these groups modified behavior to conform with feedback information. These results confirm Spiegel's distinction between similarity in the use of information and difference in the processing of information. However, under the two conditions of external feedback, poor efficiency was found only in the neurotic's processing of evaluative information. In processing non-evaluative information, normals and psychoneurotics were quite similar. It may be that Spiegel's formulation is limited to the use and processing of evaluative information.[14]

---

[14] It is interesting, here, to note the strong evaluative characteristics of linguistic communication which have been established by Osgood and his co-workers. (Osgood, Suci, and Tannenbaum, 1957).

Schizophrenic Group

The reaction of schizophrenic patients to external feedback differed markedly from the reaction of normals and psychoneurotics. Normals showed efficient combination of information from the joint occurrence of self-regulation and external feedback. Psychoneurotics showed inefficient combination of these two informational inputs. Schizophrenics failed to show either efficient or inefficient combination of self-regulation with environmental regulation.

Evaluative feedback had very little influence on the sequential choice behavior of schizophrenic patients. Praise and censure from the external environment neither increased nor decreased the extent to which their responses were predictable from the schizophrenics' own previous behavior. Thus, unlike both normals and psychoneurotics, the schizophrenic *did not* combine the evaluative environmental information with the information from his own previous behavior. Instead of combining these sources of information, the schizophrenic responded as he had when no information was available from the external environment. Thus, in the presence of evaluative feedback, the schizophrenic isolated himself from environmental information as an effective determinant of response.

This insensitivity of schizophrenics to evaluative, environmental information was reversed under conditions of non-evaluative, environmental feedback. In the presence of non-evaluative feedback the schizophrenics tended to give up their self-regulatory constraint and to modify their behavior to correspond more closely with information from the external environment. Unlike normals and psychoneurotics, who retained a limited self-regulation in combining non-evaluative feedback with previous behavior, the schizophrenics showed extreme dependence on non-evaluative information from the external environment. Thus, in the presence of non-evaluative feedback, the schizophrenic isolated himself, not from the environment, but relatively speaking, from his own previous behavior.

These opposite effects (of evaluative and non-evaluative feedback) suggest that the sequential choice behavior of schizophrenics may be understood in terms of a single underlying characteristic of information processing: Schizophrenics appear to process information by treating a multivariate bi-binary input as if they were responding to a univariate, binary input. Evaluative feedback was associated with extensive use of previous behavior and with exclusion of external feedback. Non-evaluative feedback was associated with extensive use of external feedback and with exclusion of previous behavior as a basis for responding. Thus, schizophrenics showed a lack of integration between the external regulatory demands of the environment and the self-regulatory demands of their own previous behavior.

The evaluative characteristics of external feedback were associated with significant differences in the schizophrenics' behavior. When the feedback was evaluative, responses were adapted in relation to information conveyed by previous behavior. When the feedback was non-evaluative, responses were adapted in relation to information conveyed by the external environment.

The foregoing characterization of information processing by schizophrenics differs from those of Ruesch (1957) and of Spiegel (1959). Both of these authors stressed "autistic withdrawal" from external feedback as the central concept in accounting for disordered communication in schizophrenia. In the present study, schizophrenics withdrew from environmental information *only* when it was evaluative. However, even this withdrawal cannot be said to have been accompanied by an *increase* in autistic self-regulation. Evaluative feedback simply failed to change a prior level of behavioral organization that, in comparison with the behavior of normals, was relatively insensitive to previous behavior. Moreover, when environmental information *was not* evaluative, schizophrenics did not withdraw from the informational demands of the external environment. Rather than exhibiting autistic withdrawal, schizophrenics did the opposite. They gave up self-regulation and became strongly dependent upon environmental information.

These results do not support the assertion that autistic withdrawal is a common characteristic of the schizophrenic's misuse of information. Instead the present data suggest that distorted information processing in schizophrenia is characterized by a lack of integration between self-regulation and regulation by the external environment.

An overview of results from the present study suggest a number of systematic differences in the effects of evaluation on the sequential choice behavior of groups of normal, psychoneurotics and schizophrenics. However, the generalization of these differences to other, more complex, forms of human activity is restricted in at least two ways. First, the simple informational inputs of the present study differ in many dimensions from the complicated verbal inputs which characterize most transmission of information between humans. Thus, additional experimentation is required in order to assess the extent to which results from this study may be generalized to other forms of choice behavior. Second, the diagnostic groups studied in the present experiment were representative of psychiatric illness as displayed by patients in the acute treatment centre of a university teaching hospital. However, generalization of the present results to pathologic groups in other settings and in other phases of illness must await further experimentation.

SUMMARY

This investigation was designed to study response sequences in a two-choice task with amount of sequential response constraint as the primary dependent variable. Groups of normal, psychoneurotic, and schizophrenic *Ss* were asked to generate a series of choices under three conditions of feedback: (1) the absence of external feedback, (2) the presence of evaluative feedback, and (3) the presence of non-evaluative feedback.

In the absence of external feedback, normal non-patients used the informative contingencies of their own previous behavior in a manner which corresponded with established criteria for the efficient use of information. Evaluative and non-evaluative feedback were associated with identical decreases in self-regulatory behavior and a consequent increase in regulation by information from the external environment. In both types of external feedback, normals adopted a simplifying restriction on presponse-response contingencies which compensated for the increased demands of external feedback information. Thus, for all conditions studied, the behavior of normals was characterized by maximally efficient processing of information which resulted in an efficient combination of the self-regulatory properties

of past behavior with the external regulatory demands of information from the environment.

Psychoneurotic patients resembled normals in the overall extent to which they were influenced, in responding, by their own previous behavior. However, these two groups differed markedly in the relative efficiency with which they processed the information given by sequential response constraints. In this difference information processing by psychoneurotics was less efficient, than that of normals, in failing to match the complexity of informational demands. For psychoneurotic patients, unlike normals, the change from evaluative to non-evaluative feedback produced an increase in the self-regulation of behavior. The nature of this increase suggests that psychoneurotics are more sensitive to information from the external environment when that information is conveyed by evaluative feedback.

Schizophrenic patients showed reactions to feedback conditions which differed from the reactions of both normals and psychoneurotics. In the absence of external feedback, schizophrenics were relatively insensitive to their own previous behavior, as evidenced by the minimal use of self-regulating response-response contingencies as a basis for responding. In the presence of evaluative feedback, schizophrenics did not use information from the external environment. Instead, schizophrenic patients continued to respond as they had responded in the absence of external feedback. In the presence of non-evaluative feedback, schizophrenic patients tended to abandon self-regulation and to become dependent on environmental information as the sole determinant of behavior. Thus, for all conditions studied, the behavior of schizophrenics was characterized by the almost complete lack of integration between self-regulation and regulation by information from the external environment.

APPENDICES

Appendix A

This appendix lists the coded identification, actuarial statistics, and raw data for each *S* employed in the present investigation. The data for age, education and hospitalization are summarized in Table 1.

For purposes of coded identification, the letter N designates the *Ss* in the non-patient group, the letter P identifies *Ss* in the psychoneurotic group and the letter S identifies *Ss* in the schizophrenic group. For each of these groups, the numbers 1 through 10 are used to identify those *Ss* who participated in the evaluative feedback situation and the numbers 11 through 20 identify *Ss* who received non-evaluative feedback. In each of these subgroups, the first 5 numbers designate male *Ss* and the second 5 numbers designate female *Ss*.

The numerical classification of psychopathic illness used in describing patients is that set forth in the 1952 edition of the American Psychiatric Association's *Diagnostic and Statistical Manual*. The statistical codes and equivalent verbal descriptions used in this appendix are as follows:

Psychoneurotic Disorders

000-X01	Anxiety reaction.
000-X03	Conversion reaction.
000-X04	Phobic reaction.
000-X05	Obsessive compulsive reaction.
000-X06	Depressive reaction.

Schizophrenic Reaction

000-X21	Simple reaction.
000-X23	Catatonic reaction.
000-X24	Paranoid reaction.
000-X25	Acute undifferentiated reaction.
000-X26	Chronic undifferentiated reaction.
000-X27	Schizo-affective reaction.

The data for each *S* are presented in the form suggested by Newman (1951) as being most useful in the analysis of series of binary events. The frequency, over 67 trials, of the 16 possible response tetrads is listed with the coded identification for each *S*. These frequencies may be converted directly to logarithmic equivalents and summed to obtain the values of tetradic information measures as described in Appendix B and reported in Table 2. Triad frequencies may be obtained from these lists by summing the frequency values of appropriate tetrads. For example, the frequency of occurrence of the triad R R R may be obtained directly by summing the frequencies of the tetrads R R R R and R R R L. This same procedure may be extended in order to obtain the frequencies of response diads and of single responses.

TABLE 7

Actuarial Description of Normal Subjects

Code No.	Sex	Age	Education	Occupation
N 1	M	43	16	Teacher
N 2	M	47	12	Salesman
N 3	M	20	15	Student
N 4	M	27	12	Clerk
N 5	M	31	12	Farmer
N 6	F	44	16	Housewife
N 7	F	29	12	Bookkeeper
N 8	F	49	12	Housewife
N 9	F	36	12	Clerk
N10	F	22	10	Housewife
N11	M	27	16	Student
N12	M	46	8	Truck Driver
N13	M	36	12	Artist
N14	M	42	12	Salesman
N15	M	23	16	Student
N16	F	20	12	Housewife
N17	F	31	16	Student
N18	F	41	12	Housewife
N19	F	34	12	Saleslady
N20	F	43	13	Housewife

TABLE 7—Continued

Non-feedback Frequencies of Response Tetrads for Normal Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
N 1	3	7	4	6	3	4	6	3	7	3	3	3	7	2	3	0
N 2	4	6	0	10	0	0	3	7	5	4	0	0	10	0	7	8
N 3	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N 4	0	1	0	16	0	0	15	0	1	15	0	0	16	0	0	0
N 5	0	0	0	0	0	0	0	16	0	0	0	16	0	16	16	0
N 6	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
N 7	15	5	0	5	0	0	0	5	5	0	0	0	5	0	5	19
N 8	0	0	0	16	0	0	16	0	0	16	0	0	16	0	0	0
N 9	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
N10	28	4	0	4	0	0	0	4	4	0	0	0	4	0	4	12
N11	5	8	6	6	6	1	4	3	8	3	1	1	5	2	3	2
N12	1	3	0	5	0	18	3	2	3	2	18	0	4	1	2	2
N13	0	3	3	10	4	3	9	1	3	10	4	0	10	1	1	2
N14	13	7	2	5	2	0	2	4	7	0	1	1	4	2	4	10
N15	24	3	0	3	0	0	0	3	2	0	0	0	2	0	3	24
N16	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
N17	21	6	0	6	0	0	1	5	6	0	0	0	6	0	5	8
N18	0	2	6	3	6	6	7	2	2	7	6	6	3	6	2	0
N19	0	4	0	12	0	0	7	6	4	8	0	1	12	1	7	2
N20	23	3	1	2	1	0	0	3	4	0	0	1	3	1	4	18

TABLE 7--Continued

Evaluative Feedback Frequencies of Response Tetrads for Normal Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
N 1	8	7	6	4	5	2	5	2	7	3	1	2	6	1	2	3
N 2	8	4	0	7	0	0	0	7	3	3	0	0	7	0	7	18
N 3	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N 4	23	5	0	4	0	0	0	4	4	0	0	0	4	0	4	16
N 5	3	5	5	7	5	0	4	5	5	7	0	2	8	1	5	2
N 6	9	5	4	6	4	2	4	3	5	6	2	1	6	1	3	[illegible]
N 7	11	6	4	3	4	4	1	4	5	1	4	2	2	2	3	8
N 8	1	2	3	5	3	2	3	4	2	6	2	3	5	3	5	15
N 9	22	2	0	2	0	0	0	2	3	0	0	0	3	0	3	27
N10	5	4	2	5	2	1	1	5	5	3	1	1	6	1	5	17

TABLE 7—Continued

Non-evaluative Feedback Frequencies of Response Tetrads for Normal Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
N11	3	5	5	4	3	3	1	5	5	4	1	2	6	0	5	12
N12	5	4	3	4	3	5	4	4	4	3	5	4	4	4	4	4
N13	38	4	2	2	2	0	1	1	5	0	0	0	2	0	1	6
N14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64
N15	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
N16	4	4	5	2	3	6	5	3	3	3	4	7	3	5	3	4
N17	48	1	0	1	0	0	0	1	1	0	0	0	1	0	1	10
N18	1	3	6	6	8	4	8	0	3	9	6	2	4	4	0	0
N19	5	4	2	4	2	1	3	4	5	2	1	3	5	3	5	15
N20	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0

TABLE 7--Continued

Actuarial Description of Psychoneurotic Subjects

Code No.	Sex	Age	Educ.	Occupation	Diagnosis	Days in Hospital
P 1	M	48	16	Farmer	000-X06	87
P 2	M	41	12	Contractor	000-X03	43
P 3	M	24	12	Unemployed	000-X06	17
P 4	M	36	12	Laborer	000-X06	22
P 5	M	31	11	Clerk	000-X05	27
P 6	F	27	16	Housewife	000-X06	40
P 7	F	49	12	Housewife	000-X06	32
P 8	F	33	12	Housewife	000-X05	70
P 9	F	50	10	Housewife	000-X06	28
P10	F	23	16	Teacher	000-X06	14
P11	M	31	13	Unemployed	000-X06	38
P12	M	36	12	Salesman	000-X06	25
P13	M	20	13	Student	000-X01	23
P14	M	49	16	Teacher	000-X05	71
P15	M	41	12	Contractor	000-X06	41
P16	F	33	16	Housewife	000-X04	21
P17	F	35	12	Housewife	000-X06	35
P18	F	40	16	Housewife	000-X05	43
P19	F	33	16	Housewife	000-X06	60
P20	F	40	10	Housewife	000-X06	45

TABLE 7—Continued

Non-feedback Frequencies of Response Tetrads for Psychoneurotic Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
P 1	5	10	4	8	4	0	1	7	10	1	0	0	7	0	6	1
P 2	0	2	4	3	4	12	6	1	2	6	12	4	4	3	1	0
P 3	3	6	9	7	10	0	5	1	6	10	0	0	6	0	1	0
P 4	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
P 5	3	5	2	7	3	4	2	6	5	4	4	1	7	1	6	4
P 6	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
P 7	24	5	2	4	2	0	2	2	6	0	0	0	4	0	2	11
P 8	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
P 9	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
P10	11	7	2	6	2	1	1	7	6	1	1	2	5	2	7	3
P11	1	3	3	7	6	1	5	5	4	7	4	2	5	5	5	1
P12	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
P13	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P14	6	5	3	4	2	5	3	4	6	2	4	3	5	2	4	6
P15	1	6	2	8	0	4	4	6	6	4	2	2	10	0	6	3
P16	0	3	0	5	4	13	5	2	3	2	16	2	2	5	2	0
P17	2	5	4	8	6	2	5	4	4	7	4	1	5	3	3	1
P18	0	1	6	4	4	6	7	3	1	8	5	6	5	5	3	0
P19	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
P20	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0

TABLE 7—Continued

Evaluative Feedback Frequencies of Response Tetrads for Psychoneurotic Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
P 1	0	2	0	9	0	3	9	4	2	7	3	4	9	3	3	6
P 2	8	5	1	6	2	1	4	4	5	2	2	2	5	3	4	10
P 3	1	5	10	4	10	0	5	2	5	8	1	3	3	4	2	1
P 4	5	3	5	3	3	6	10	0	3	5	5	6	5	5	0	0
P 5	12	6	2	8	1	2	6	3	5	4	1	2	8	1	3	0
P 6	20	2	1	2	0	3	0	4	2	1	2	2	3	1	4	17
P 7	0	2	4	8	5	3	8	3	2	10	4	3	6	4	2	0
P 8	47	3	4	0	4	1	0	0	3	1	1	0	0	0	0	0
P 9	2	5	1	4	5	7	7	2	5	0	11	4	1	8	2	0
P10	7	4	0	8	0	0	7	4	4	4	0	3	8	3	5	7

TABLE 7--Continued

Non-evaluative Feedback Frequencies of Response Tetrads for Psychoneurotic Subjects

Code No.	NNNN	NNNL	NNLN	NNLL	NLNN	NLNL	NLLN	NLLL	LNNN	LNNL	LNLN	LNLL	LLNN	LLNL	LLLN	LLLL
P11	20	8	1	7	1	0	3	4	8	0	0	0	7	0	4	1
P12	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
P13	1	5	3	6	3	3	2	6	5	5	3	2	7	2	7	4
P14	5	5	4	7	5	1	6	3	4	7	2	2	6	3	3	1
P15	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
P16	48	1	0	1	0	0	0	1	2	0	0	0	2	0	2	7
P17	4	4	3	7	2	1	9	3	3	6	0	6	7	5	3	1
P18	11	6	4	3	4	4	1	4	5	1	4	2	2	2	3	8
P19	0	1	3	1	0	13	10	0	1	3	11	9	4	7	1	0
P20	7	6	1	8	2	0	5	5	7	3	1	2	8	3	5	1

TABLE 7--Continued

Actuarial Description of Schizophrenic Subjects

Code No.	Sex	Age	Educ.	Occupation	Diagnosis	Days in Hospital
S 1	M	42	12	Clerk	000-X26	65
S 2	M	33	16	Teacher	000-X24	57
S 3	M	51	12	Salesman	000-X24	41
S 4	M	22	13	Student	000-X21	54
S 5	M	28	12	Unemployed	000-X24	108
S 6	F	25	12	Housewife	000-X21	113
S 7	F	24	16	Teacher	000-X21	51
S 8	F	52	16	Secretary	000-X23	62
S 9	F	42	15	Housewife	000-X27	115
S10	F	38	10	Housewife	000-X24	91
S11	M	21	13	Student	000-X25	28
S12	M	34	16	Teacher	000-X24	57
S13	M	41	12	Clerk	000-X26	28
S14	M	28	12	Technician	000-X25	93
S15	M	53	16	Teacher	000-X24	97
S16	F	46	13	Housewife	000-X26	57
S17	F	24	15	Housewife	000-X27	18
S18	F	49	12	Housewife	000-X25	41
S19	F	33	8	Housewife	000-X21	45
S20	F	31	12	Bookkeeper	000-X24	84

TABLE 7—Continued

Non-feedback Frequencies of Response Tetrads for Schizophrenic Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
S 1	0	3	2	7	2	5	5	5	3	6	5	3	7	4	6	1
S 2	9	5	0	6	1	3	4	5	6	1	3	3	6	3	5	4
S 3	0	0	5	0	2	19	5	1	0	5	15	6	3	2	1	0
S 4	0	0	3	6	4	6	10	1	0	10	7	5	6	5	1	0
S 5	3	4	0	8	1	0	3	8	5	4	1	3	8	3	8	5
S 6	0	1	3	11	3	1	10	3	1	13	1	2	11	1	3	0
S 7	0	0	8	0	4	15	7	0	0	6	12	7	2	5	0	0
S 8	1	10	7	6	8	4	4	1	10	3	4	0	5	0	1	0
S 9	15	8	1	7	2	1	0	6	8	0	1	0	6	0	6	3
S10	0	1	5	0	5	24	0	0	1	4	24	0	0	0	0	0
S11	0	7	1	10	0	1	4	8	7	4	0	2	11	1	8	0
S12	0	2	3	7	3	7	9	1	2	8	7	4	6	4	1	0
S13	16	5	0	5	0	0	0	5	4	0	0	0	4	0	4	21
S14	1	1	0	4	0	0	18	1	1	3	0	15	4	14	1	1
S15	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0
S16	7	4	0	11	1	0	7	4	4	7	1	0	10	0	3	5
S17	1	5	4	7	6	1	4	5	6	6	2	2	6	3	5	1
S18	4	6	3	6	1	3	4	5	6	4	1	3	9	0	5	4
S19	25	4	0	5	0	0	1	4	4	1	0	0	5	0	4	11
S20	6	6	0	7	0	0	1	8	6	1	0	2	7	2	8	10

TABLE 7—Continued

Evaluative Feedback Frequencies of Response Tetrads for Schizophrenic Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
S 1	0	3	7	1	6	15	4	0	3	5	14	2	2	2	0	0
S 2	0	4	0	12	1	0	7	5	5	8	1	0	12	1	6	2
S 3	0	2	0	9	1	4	7	5	2	7	6	3	7	5	5	1
S 4	6	6	0	6	0	0	0	8	6	0	0	2	6	3	8	13
S 5	4	4	3	5	3	4	4	4	4	4	4	3	5	4	4	5
S 6	0	1	6	5	2	8	7	3	1	10	3	5	9	1	3	0
S 7	0	0	5	6	6	6	7	2	0	12	6	3	6	3	2	0
S 8	10	7	1	8	2	1	0	7	7	2	1	0	7	0	7	4
S 9	4	6	0	10	0	0	5	6	6	4	0	0	11	0	6	6
S10	0	0	0	0	0	32	0	0	0	0	32	0	0	0	0	0

TABLE 7--Continued

Non-evaluative Feedback Frequencies of Response Tetrads for Schizophrenic Subjects

Code No.	RRRR	RRRL	RRLR	RRLL	RLRR	RLRL	RLLR	RLLL	LRRR	LRRL	LRLR	LRLL	LLRR	LLRL	LLLR	LLLL
311	3	4	3	7	2	10	5	2	4	5	9	1	7	0	2	0
312	4	4	4	4	5	4	4	4	4	4	5	3	4	4	4	3
313	0	0	1	0	1	30	0	0	0	1	31	0	0	0	0	0
314	3	1	1	1	1	4	3	7	1	2	4	9	2	8	7	10
315	7	4	5	3	5	4	2	4	4	3	4	4	2	4	4	5
316	3	4	4	4	5	7	5	2	4	4	8	2	3	3	2	4
317	4	6	3	6	2	2	2	6	6	2	1	3	6	2	6	7
318	4	3	4	3	4	4	3	3	3	4	4	4	3	4	4	10
319	4	4	4	4	3	3	4	5	4	4	2	5	5	4	5	4
320	4	4	4	6	4	4	4	4	4	6	4	2	6	2	4	2

Appendix B

Information Measurement

Information theory specifies a quantitative relationship between the amount of information (H') given by the occurrence of an event and the number of ways (k) in which that event may occur.

$$H' = \log_2 k \qquad (1)$$

Equation (1) states that the value of H' (information given by the occurrence of an event) is equal to the logarithm of k (the number of ways in which that event may occur). By convention, $\log_2$ is employed in information measurement and the resulting value of H' is said to be expressed in units of binary digits or "bits" of information.

The utility of expressing information as a bit value based on the logarithmic relationship can be seen within the context of the present experiment. When S makes a single choice between two buttons, he may exhibit either of two outcomes; Left (L) or Right (R). The bit value of information given by a single choice, H' (1), equals $\log_2 2$ or 1 bit of information. A sequence of two choices may exhibit any of the four outcomes, RR, RL, LR, LL. The bit value of information given by two consecutive choices; H' (1,2) equals $\log_2 4$ or 2 bits of information. Three consecutive choices exhibit eight possible outcomes. Thus, H' (1,2,3) equals $\log_2 8$ or 3 bits of information. The logarithmic measure ensures that bit value of information (H') is a monotonically increasing function of the number of possible outcomes of an event (k).

By considering the values of variables as events, it is possible to generalize Equation 1 to include events with any number of outcomes and to measure information when all outcomes are not considered to be equally probable.

Consider first the equiprobable case in which variable x may assume values x_i where i = 1,2,.....,k. Since all values of x_i are equally probable, then:

$$H'(x) = \log_2 k$$

In the equally probable case, the probability of any particular outcome, x_i [p(x)] is expressed as the reciprocal of the number of events in x_i, thus:

$$p(x) = {}^1/_k.$$

$$\text{But, } H'(x) = \log_2 k \qquad (1)$$

$$\text{Thus, } H'(x) = -\log_{2p(x)} \qquad (2)$$

In the equally probable case, $H'(x)$ is the information in any particular category of the variable x, and at the same time $H'(x)$ is the information in all categories of that variable.

When the categories of x_i are not equally probable, Equation 2 must be modified in such a way as to accomplish two purposes. First, it must distinguish the information in any one category of x_i from the average information in all x_i. Second, it must give the average information for all x_i after weighting the information for each x_i by the probability of its occurrence. Shannon and Weaver (1949) have shown that when $H'(x)$ is defined as in Equation 3,

$$H'(x) = -\sum_i p(x) \log_2 p(x). \qquad (3)$$

In this equation, $H'(x)$ represents the average amount of information contained in the repeated occurrence of event x_i and is dependent upon both the number of ways in which x_i can occur and the probabilities associated with each of these occurrences.

Univariate Information

In the context of the present experiment, $H'(x)$ may be replaced by $H'(1)$ signifying the average amount of information contained in a sequence of 64 consecutive responses. As such, the value of $H'(1)$ is free to vary between 0 and 1 bits of information because any given response may occur in either of two ways (i.e., Right or Left). At the same time, the actual value of H' (1) depends on the actual frequencies with which any *S* distributed his responses over the entire sequence of trials. Thus, H' (1) is a summary statistic expressing the amount of information contained in the relative frequency distribution of single responses over a series of responses.

In order to extend this form of analysis beyond the single response level, it is necessary to establish a system for enumerating each of the events in a response sequence. Our ultimate interest lies in examining the relationships between any response and the responses which preceded it. Therefore, a backward enumeration is convenient in which the last response is labeled 1, its predecessor is labeled 2, etc. Thus, a sequence of responses would appear as n....4321. In this notation, H' (1) refers to *response* information, i.e., the last event in a sequence. H' (2) refers to *preresponse* information, i.e., the event immediately preceding the last event in a sequence. H' (3) refers to preresponse information twice removed from a given response. H' (4) refers to preresponse information removed by three events from the response.

With this notation in mind, it is possible to determine preresponse information, H' (2), by treating it as a variable, y, with values y_j where $j = 1,2,3...k$. By analogy with Equation 3 we obtain,

$$H' (2) = -\sum_{j} p(y) \log_2 p(y). \qquad (4)$$

In this equation, H'(2) represents the average amount of information contained in a sequence of 64 presponses (when, of course, they are followed by 64 responses).

By extension of the above procedure, it is possible to complete the analysis of univariate sources of information in sequence of length four: H' (3) represents information contained in presponses twice removed from responses, H' (4) represents information contained in presponses removed by three events from responses.

Multivariate Information

In addition to the univariate measures of information described above, the joint occurrence of two or more events in a sequence may convey information. For example, consider a sequence of response events generated by simple alternation: H, L, H, L, ...n. In such a sequence, each response is equally frequent; thus H' (1) assumes a maximum value. Given any response, its immediate predecessor will be H or L with equal frequency. Thus H' (2) will be maximum. However, the joint occurrence of a presponse-response diad will not generate all possible values of this bivariate distribution. Half of all values will be H, L. The other half of values will be L, H. The values H, H and L, L will never occur in a simple alternation sequence. Thus, the bivariate expression of information may differ from its univariate components.

The bit value of bivariate sources of information may be computed by extending the technique employed for univariate computation. In the bivariate case, let H' (1) be treated as a variable, x with values x_i where $i = 1,2,3,..k$. Let H' (2) be treated as a variable, y, with values y_j where $j = 1,2...k$. By extension of Equation 3 we obtain:

$$H' (1,2) = -\sum_{ij} p(xy) \log_2 p(xy) \qquad (5)$$

In Equation 5, H' (1,2) represents the amount of information contained in the joint occurrence of presponse-response diads over the course of a series of trials.

By analogy with Equation 5 it is possible to obtain values for each of the eleven bivariate, trivariate, and quadrivariate sources of information that may exist in the analysis of sequence of four events.

The Measurement of Multivariate Information

In the preceding section, it was noted that the amount of information in a multivariate expression may differ from the sum of information given by its univariate components. This inequality may be used to generate additional information measures which reveal the nature of sequential ordering in a series of events.

If responses are totally independent of presponses, the amount of information given by their joint occurrence should be equal to the sum of their individual information;

i.e., $H'(1) + H'(2) = H'(1,2)$. This form of independence is exemplified by a sequentially random series of Right and Left choices in which all presponses, responses and presponse-response diads occur with equal frequency. If, on the other hand, responses are sequentially dependent on presponses, then $H'(1) + H'(2) > H'(1,2)$. Letting $T'(1;2)$ stand for this inequality, we derive the equation

$$T'(1;2) = H'(1) + H'(2) - H'(1,2) \qquad (6)$$

in which $T'(1;2)$ represents (in "bit" units of information) the amount of redundancy or *sequential constraint* that exists between presponses and responses.

Sequential constraint between presponses and responses reflects the extent to which an individual is influenced by his own previous behavior. This influence is manifested in the amount by which $H'(1,2) < H'(1) + H'(2)$. When this influence is persistent over the course of a performance, the value of sequential constraint measures will be high. If, on the other hand, sequential ordering drops toward randomness, then information measures of constraint approach zero. Because of the equivalence of constraint and sequential ordering, it is possible to interpret measures like $T'(1;2)$ as estimates of predictability. Thus, the bit value of $T'(1;2)$ represents both the sequential constraint between presponses and responses and the predictability of responses from presponses.

Response predictability may be increased by a knowledge of more than one presponse. The computation of more complex sources of predictability is accomplished by elaborating Equation 6. For example:

$$T'(1;23) = H'(1) + H'(2) + H'(3) - H'(1,2,3) \qquad (7)$$

where $T'(1;23)$ represents the average predictability of a response given by the information contained in the joint occurrence of its first and second presponses.

Equation 7 generates the information value of predictability for the joint occurrence of presponse events 2 and 3. In order to specify the constraint between 3 (a presponse once removed) and the response, 1, it is necessary to remove the interactive effect of 2 with 3. Thus,

$$T'_2(1;3) = T'(1;23) - T'(1;2)$$

where $T'_2(1;3)$ represents the constraint between responses and presponses once removed with the intervening presponse held constant. Stated in a different way,

$$T'(1;23) = T'(1;2) + T'_2(1;3),$$

that is, response predictability derived from the joint occurrence of two presponses is equal to the sum of the predictabilities from each presponse alone.

By extending this computational procedure it is possible to derive a summary statistic which characterized all of the sequential constraint in a sequence of events. Garner (1962) has called this measure, "Total sequential constraint," and shown that it consists of the sum of all response predictabilities as follows:

$$T'(1;2;3;4) = T'(1;2) + T'(1;23) + T'(1;234)$$

The bit value of $T'(1;2;3;4)$ represents the total sequential constraint in a series of preresponses and responses due to the effects of constraint between and among the various events in the sequence of four trials.

Table 2 reports the bit value of $T'(1;2;3;4)$ for the data from the present investigation.

The Analysis of Multivariate Information Measures

It is possible to partition total sequential constraint into its component parts:

$$\begin{aligned} T'(1;2;3;4) &= T'(1;2) + T'(1;23) + T'(1;234) \\ T'(1;234) &= T'_{23}(1;4) + T'(1;23) \\ T'(1;23) &= T'_{2}(1;3) + T'(1;2) \end{aligned}$$

This partitioning allows exact specifications of response predictability based on each of three preresponses alone: $T'(1;2)$, $T'_{2}(1;3)$, and $T'_{23}(1;4)$. In addition, partitioning allows specification of response predictability based on the joint occurrence of two or more responses: $T'(1;23)$, and $T'(1;234)$. Thus, it is possible to specify the response predictability (in bits of information) that is associated with each of the following multivariate sources of information.

$T'(i;2)$	Response predictability associated with the immediate presponse alone.
$T'_2(i;3)$	Response predictability associated with the presponse removed by one event; i.e., the second presponse alone.
$T'_{23}(i;4)$	Response predictability associated with the presponse removed by two events; i.e., the third presponse alone.
$T'(i;23)$	Response predictability associated with the joint occurrence of the first and second presponses.
$T'(i;234)$	Response predictability associated with the joint occurrence of the first, second, and third presponses.

The result of such a partitioning of data from the present investigation is reported in Table 2.

The Asymptotic Distribution of Information Measures

McGill (1954) has shown that bit values for both H' and T' measures are related to $\underline{X}^2$ in such a way that, when N equals the number of events in a sequence,

$$\underline{X}^2 \doteq 1.3863\ N \times T' \text{ (or } H'\text{)},$$

He also has shown that, when k equals the number of alternative outcomes which a variable may assume, df for testing $\underline{X}^2$ are equal to k - 1. Thus, it is possible to test the null hypothesis that any observed value of H' or T' is zero. Rejection of this hypothesis permits inferences that the particular presponse-response relationship tested contains a statistically significant amount of information.

The relationship between information measures and $\underline{X}^2$ also provides a test for the statistical significance of differences between pairs of values of H' or T'. The ratio of two values of $\underline{X}^2$, each divided by its df, is distributed as F. By transforming values of H' and T' to their $\underline{X}^2$ approximations, it is possible to employ the F distribution as a statistical test for the significance of differences between information measures.

Table 3 reports the F values for comparisons of total sequential constraint, T' [1;2;3;4)] between the three diagnostic groups and the three experimental conditions employed in the present investigation.

References

Anderson, N. H. Effect of first-order conditional probabilities in a two-choice learning situation. *J. exp. Psychol.*, 1960, *59*, 73-93.

Atkinson, Rita L., and Robinson, Nancy M. Paired-associates learning by schizophrenic and normal subjects under conditions of personal and impersonal reward and punishment. *J. abnorm. soc. Psychol.*, 1961, *62*, 322-326.

Attneave, F. *Applications of information theory to psychology.* New York: Holt, 1959.

Bakan, P. Response tendencies in attempts to generate random binary series. *Amer. J. Psychol.*, 1960, *73*, 127-131.

Bennett, W. F., Fitts, P. M., and Noble, M. The learning of sequential dependencies. *J. exp. Psychol.*, 1954, *48*, 303-312.

Cohen, B. D. Motivation and performance in schizophrenia. *J. abnorm. soc. Psychol.*, 1956, *52*, 186-190.

Davis, P. J. *The lore of large numbers.* New York: Random House, 1961, Pp. 69-71.

Dowie, J. L. and Pawliger, D. Computational methods useful in multivariate information analysis. *Psychometrika*, in press, 1964.

Edwards, W. Methods for computing uncertainties. *Amer. J. Psychol.*, 1954, *67*, 164-170.

English, H. B., and English, Ava C. *A comprehensive dictionary of psychological and psychoanalytical terms.* New York: Longmans, 1958.

Eriksen, C. W., and Wechsler, H. Some effects of experimentally induced anxiety upon discrimination behavior. *J. exp. Psychol.*, 1955, *50*, 153-160.

Estes, W. K. The statistical approach to learning theory. In S. Koch (Ed.), *Psychology: A study of a science*, Vol. 2. New York: McGraw-Hill, 1959, Pp. 380-491.

Garmezy, N. Stimulus differentiation by schizophrenic and normal subjects under conditions of reward and punishment. *J. Pers.*, 1952, *20*, 253-276.

Garner, W. R. *Uncertainty and structure as psychological concepts*. New York: Wiley, 1962.

Goodfellow, Louis D. A psychological interpretation of the results of the Zenith radio experiments in telepathy. *J. exp. Psychol.*, 1938, *23*, 601-632.

Grant, D. A., Hake, H. W., and Hornseth, J. P. Acquisition and extinction of a verbal conditioned response with differing percentages of reinforcement. *J. exp. Psychol.*, 1951, *42*, 1-5.

Hake, H. W., and Hyman, R. Perception of the statistical structure of a random series of binary symbols. *J. exp. Psychol.*, 1953, *45*, 64-74.

McGill, W. J. Multivariate information transmission. *Psychometrika*, 1954, *19*, 97-116.

Newman, E. B. Computational methods useful in analyzing series of binary data. *Amer. J. Psychol.*, 1951, *64*, 252-262.

Osgood, C. E., Suci, G. J., and Tannenbaum, P. H. *The measurement of meaning*. Urbana: U. of Ill. Press, 1957.

Pollack, I. Assimilation of sequentially encoded information. *Amer. J. Psychol.*, 1953, *66*, 421-435.

Popper, K. R. *The logic of scientific discovery*. New York: Basic Books, 1959, Pp. 158-163, 292-295.

Ruesch, J. *Disturbed communication*. New York: Norton, 1957.

Ruffin, W., Coggins, Deborah, and Dowie, J. Integration of acute schizophrenic patients into an open treatment unit., in preparation, 1964.

Senders, Virginia L., and Sowards, Ann. Analysis of response sequences in the setting of a psychophysical experiment. *Amer. J. Psychol.*, 1952, *65*, 358-374.

Senders, Virginia L. Further analysis of response sequences in the setting of a psychophysical experiment. *Amer. J. Psychol.*, 1953, *66*, 215-228.

Shannon, C. E., and Weaver, W. *The mathematical theory of communication.* Urbana: Univ. of Ill. Press, 1949.

Skinner, B. F. The process involved in the repeated guessing of alternatives. *J. exp. Psychol.*, 1942, *30*, 495-503.

Spiegel, Rose. Specific problems of communication in psychiatric conditions. In S. Arieti (Ed.), *American Handbook of Psychiatry.* Vol. 1. New York: Basic Books, 1959, Pp. 909-949.

Yacorzynski, G. K. Perceptual principles involved in the disintegration of a configuration formed in predicting the occurrence of patterns selected by choice. *J. exp. Psychol.*, 1941, *29*, 401-406.

Biographical Sketch

James Lee Dowie was born December 3, 1924, at Mankato, Minnesota. In June, 1942 he graduated from Dwight Morrow High School in Englewood, New Jersey. From 1942 until 1943 he attended the University of Maine as a member of the Army Specialized Training Program and subsequently served in the Thirty-sixth Infantry Division of the United States Army. From 1943 until 1945 he was stationed in the European Theater of Operations.

Following his discharge from the Army, in March, 1945, Mr. Dowie attended the University of Southern California where he studied journalism. From 1945 until 1951 Mr. Dowie worked as an advertising copywriter. In 1951 he enrolled in the Department of Psychology at Florida State University and received the degree of Bachelor of Science in 1952 and the degree of Master of Science in 1953. From 1953 until 1955 he worked as a research psychologist at Yerkes Laboratories of Primate Biology, and in 1955 was appointed as a lecturer in the Department of Physiology at New York University. From 1955 until 1957 he attended the National Psychological Association for Psychoanalysis in New York City. In 1956 Mr. Dowie became a Research Associate in the Department of

Psychiatry at the Cornell University College of Medicine. In 1958 he accepted an appointment as Research Associate in the Department of Psychiatry at the University of Florida College of Medicine, where he is currently employed. In 1958 Mr. Dowis enrolled in the Graduate School of the University of Florida. He worked as a National Institute of Mental Health (NIMH) predoctoral fellow in the Department of Psychology from 1958 until 1960. In 1959 he was named Co-principal Investigator of an NIMH grant to study patterns of thinking in psychiatric illness.

James Lee Dowis is married to the former Virginia Schafer and is the father of two children. He is a member of The American Psychological Association, The Southeastern Psychological Association, The Florida Psychological Association, The American Association for the Advancement of Science, and the American Association of University Professors.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

April 18, 1964

Dean, College of Arts and
Sciences

Dean, Graduate School

Supervisory Committee:

HD Kimmel
Chairman

Clyde Morris